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Characterisation and conformation of structural Morphometry of Rajatkrishna impact crater, Sindudurg district of Maharashtra, India

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Abstract

Rajatkrishna impact crater is an unique geological system being the only meteoritic crater in lateritic terrain in the world. Crater is unique due to its lithostructural characterisation and surrounding associated location of smaller companion craters i.e. Antariksha crater, Neel crater and Sindhu crater etc craters. The main aim and objective of this research paper is to identify geomorphic structure and its morphometric units of the impact craters using the Remote sensing data i.e Drone image, Google Earth data and GPS survey. Detailed analysis of crater attributes like shape and size of the craters and other morphological aspects like size ,shape ,depth and slope aspect etc. parameters, which can resolve many outstanding issues in science. In the present research paper authors have mostly focused on delineation of impact craters. Now a days advanced techniques like Remote sensing can be use to determine the impact structure on the earth.A Simple bowl (orthogonal/spheroidal) shape of the crater determined using the morphological geological, topographical studies. Among different studies, Geomorphological investigation indicates that crater's shape and morphology is quite obvious with a simple bowl projection; as well as litho-structural pattern provides very strong evidence for possible impact structure, indicating the presence of circular circumference of 525 mts and 220 mts N-S and 190 E-W provides accurate shape and vertical rim 5 mts with 45 to 70 degree slope indicates perfect bowl shape , its cavity ratio and associated Antriksha, Neel and Shindu etc smaller companion craters gives perfect evidence to impact origin of Rajatkrishna crater.

Keywords: Impact craters, morphometry, meteor shower ,ejecta blanket ,Nonperineal impact crater

1.Introduction

The Rajatkrisna meteoritic crater is a non perennial impact crater located on lateritic terrain of the Khamda plateau region It is south side of Chaukul village in Sawantwadi tahsil in Sindhudurg district of western Maharashtra. Hence it is only one meteoritic crater in the world which is located on lateritic terrain. Its GPS location is 15º 52'39.5"N latitude and 74º1'34.5"E longitude. It is only one hypervelocity impact crater in western Ghat region which is located 630 mts from the mean sea level. Mean rainfall of the region is 7477mm and alternative wet and dry situation present annually. It is 10 Km south from Amboli hill station and 30 km East from Sawantwadi.

Impact crater is a very unique geomorphic and geological process. Due to impact temperature releases vey high than the nuclear bomb it depends on the speed of the meteor. It also affects the surrounding environment and biodiversity. During the Jurassic period most of the dinosaur extinct due to deep impact vies a versa origin of life occurs due to the change in climate**.** [(1)]

2. Objectives

1. To determine the first impact structure of the lateritic terrain in the world.
2. To provide morphometric evidence in support of the impact structure.

3. The Study area

The Rajatkrisna crater located at Chaukul village of Sawantwadi tahsil of Sindhudug district of konkan region of Maharashtra. It is located at 15º 52'39.5"N latitude and 74º1'34.5"E longitude.

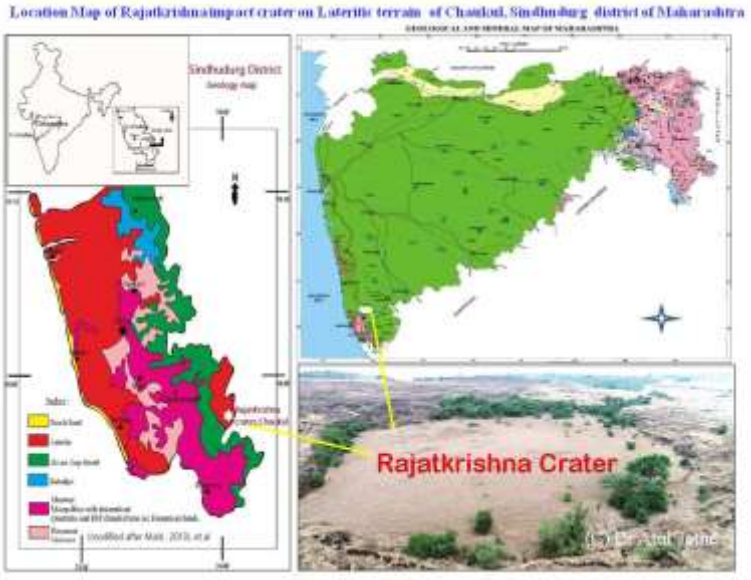

Fig.No.1. Location map and drone view of Rajatkrishna crater

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4. Materials and Methods

4.1. Data sources

Following data sources is acquired to understand the characterization and Morphometry;

4.1.1. Drone image:

High resolution (1:10,000) vertical image was acquired from drone Sawantwadi Govt. of Maharashtra. It is used for further analysis to determine the elongation ratio ,size and shape of the crater.

4.1.2. IRS 1C LISS III image:

The image was acquired from NRSA, ISRO dept. India for the segmentation of Rajatkrishna crater Sindhudurg district of Maharashtra.

4.1.3. Geology Map

The Geology map of Maharashtra was acquired from GSI ,Pune for the delineation of geomorphic units of Rajatkrishna impact crater, Maharashtra.

1.4.4. GPS survey:

The study area were tracked and surveyed by GPS**.** The soil sample points were tracked by using GPS.

1.4.5. Field Work, Rock and Soil samples Collection:

In order to study the physico-chemical properties of the soil around 10 soil samples and rocks have been collected from the crater area using GPS and analysed in the soil laboratory.

5. Result and Discussion:

Simple bowl craters are result of small meteoritic impact events. Especially the craters which are less than 250. To 500 meters in diameters. Simple bowl craters common rocky bodies of the surfaces such craters are easy to observe and well preserved, it provides the shape, size and diameter ratio etc records for rate of impacts**.**[(2)] Now a days topographical maps , aerial photographs , Rs and GIS data techniques are become very effective techniques to provide the database of impact craters. It also provides detailed database about excavated cavity ratio, crater rim, ejecta blanket, basin floor as well as Stratigraphy of the crater. The simple impact crater also provides data about fractures, melted and vaporize material which are depending on diameter and size of the crater. [(2)]

5.1 Geometry of the crater

The geometry of craters gives details of catering mechanisms, modification of crater morphology with time.The image interpretation elements i.e size, shape, texture, pattern ,tone and association etc. elements are important for identification of the impact crater. The tone of the Rajatkrishna crater and the textural variation is gradual due to ejecta outside the rim of the crater.

5.1.1 Circularity index of the Rajatkrishna crater

Crater's first identity is its circular bowl shape. Each and every impact crater has its own unique shape. Shape of the crater can be compared with circle to understand its deviation from the edges. It can be expressed by the circularity index of the crater.

Circularity index of the crater (CI) = 4*PI

i.e area of the crater/Perimeter of the crater. The circularity values ranges between 0 to 1. Hence '0' indicates the elliptical shape of the crater where as '1' value indicates a perfect circular shape of the crater. Hence CI of the Rajatkrishna crater is 0.9 that is near to 1 .It indicates perfect circularity index of the crater

Fig.No.2. Drone view of Rajatkrishna crater showing cirularity ratio

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5.1.2 Size of the crater

The perfect rim diameter of the crater is 190 mts. It means calculated circularity index does not show its circularity but it is near to circularity. The north to south diameter of the crater is 220mts while East to West diameter is 190 mts. Hence the circularity of the crater correlates different directions as well as the size of the crater varying through out of the crater rim.

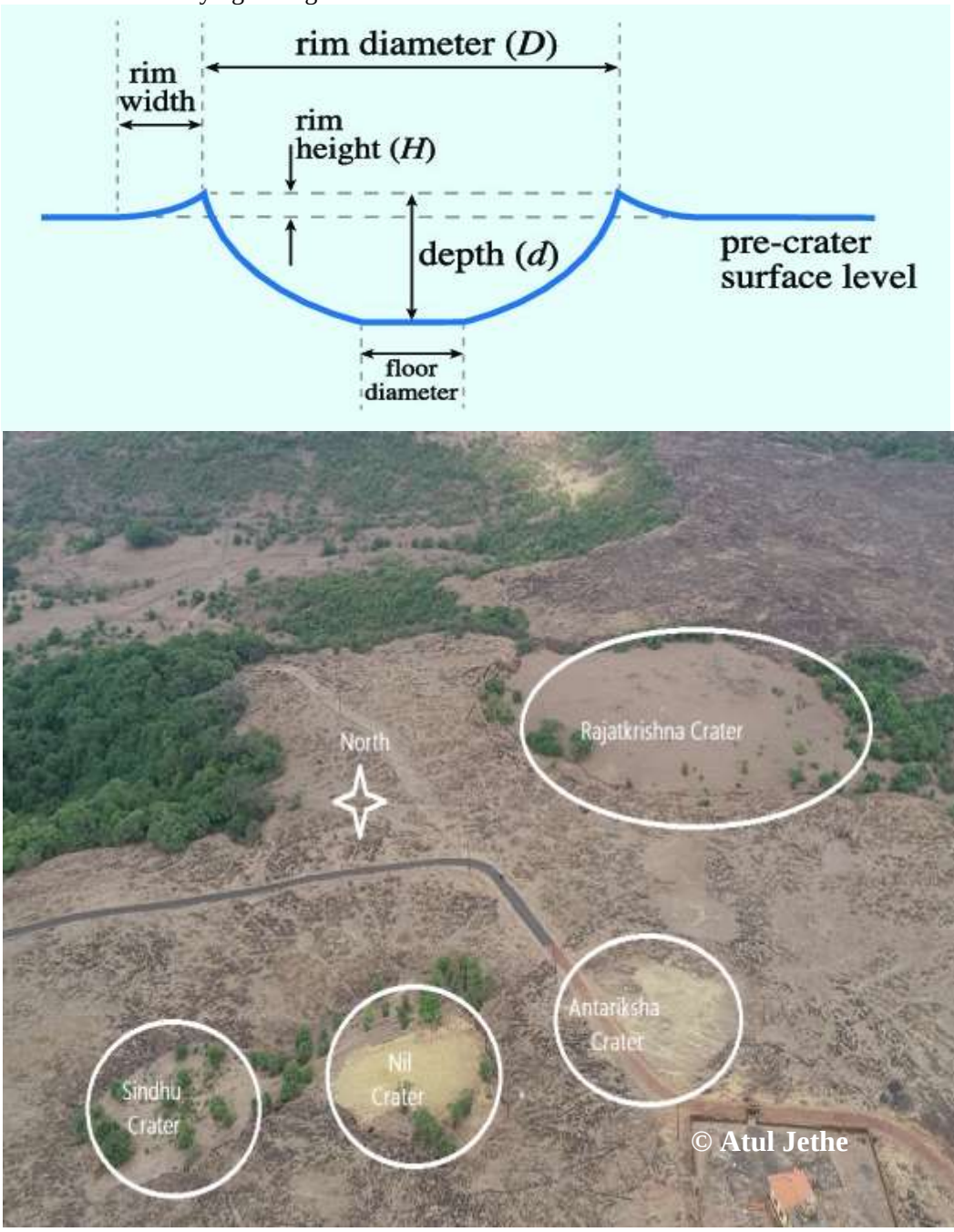

Fig. No.3. Morphometry and Meteor shower near Rajatkrishna crater

5.1.3 Crater Association

Due to meteoritic impact , not only a crater forms but also its impact ejecta blanket which extend outward direction , smaller companion craters as well as structural disturbances and deformations also observes along the peripheral region of the crater. Such types of associated features are important elements for identification of impact craters. Hence Rajatkrishna crater and its associated impact craters i.e. Antriksha crater, Neel crater and Shindhu crater etc associated impact craters and its ejecta bnket determines formation result of these impact craters due to meteor shower.

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5.1.4. The Ejecta Blanket of the crater

Ejected outward material of the crater is an important aspect for the interpretation of the crater because most of the impact craters are associated with ejacta blanket. It gives detailed result about the intensity of impact (Pierazzo and Melosh, 2000).Hence distribution of ejecta blanket along the direction of the crater is also important aspect to understand not only intensity of the impact but also the speed, weight and size of the meteorite. Hence due to plateau region of Khamda as well as heavy rainfall and very high soil loss region of Maharashtra therefore Rajatkrishna meteoritic crater as well as its associated impact craters has very little elevated ejecta blanket.[3]

5.1.5. Crater Rim and Slope

Crater rim is an important geomorphic aspect of the Rajatkrishna impact crater. West side of the crater is characterised by 45° slope while East side of the crater characterised by 70° slope. In short west side having more accessibility than the east side. Crater is broken by a stream which is flowing SSW to NNE direction. So slope of the crater region is sloping towards north direction.

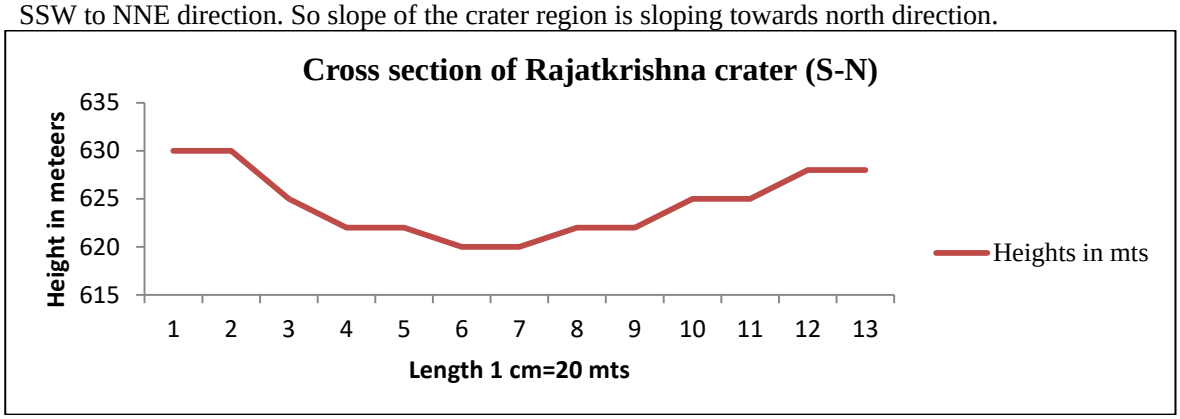

Fig. No. 4 Cross section of Rajatkrishna crater (S to N)

5.1.6 Mobility of Ejecta blanket

Geomorphic processes and external forces decline the areal extent of the ejecta. Mobility of the crater also depends on the size of the impact crater. It may reduce the size and shape of the crater (Mark, 1979) following formula used to describe relationship of ejecta mobility.

Ejecta Mobility= Average extent of ejecta layer/radius of the crater[4]

The mobility of the ejecta provides the information of viscosity of the material.

Hence ejecta blanket of the Rajatkrishna crater eroded due to fluvial erosion and heavy soil loss.

5.1.7 Albedo and Shape of the Ejecta-Blanket

Shape of the ejecta blanket depends on the impact angle of the crater (Gaco Komatsu et.al.2014), Gravity level as well as presence and absence of micro climate inside of the crater. Hence Rajatkrishna crater ejecta is near circular shape. Hence the albedo and the shape of the Rajatkrishna crater is somewhat elongated due to its rim broken due to stream erosion .Therefore hence North to South diameter of the crater is 220 mts while East to West diameter is 190 mts.[5]

5.1.8 Sharpness of the Rim

Lithostructural control of the crater determines the sharpness of the crater. Weathering process depends upon the structure, geomorphic processes and other related factor determines the sharpness of the crater. Edges of the crater modifies due to erosion and intensity of the soil loss and surface run off present in the study area.[6]

5.1.9. Elongation Ratio (Re)

Elongation ratio of the meteoritic crater can be defined as the ratio of the crater's rim circle diameter. It should be equal or same to the maximum basin lengh. Strahler states about the ratio of the crater basin should be between 0.6 to 1.0 wide variety of diameter and geologic type. Varying shapes of the crater can be categorised using elongation ratio when ratio ranges in between 0.9 to 1.0 it is known as Circular elongation index; when it lies in between 0.8 to 0.9 it is known as oval shape; if it lies in between 0.7 to 0.8 it is called as less elongated index; if it is lies in between 0.5 to 0.7 it is known as elongated and when it is <0.5 its known as highly elongated.The elongation ratio of the Rajatkrishna crater crater as **Re=0.75.** It meanse Rajat Krishna crater is less elongated in shape. The lower the elongation ratio, higher the priority level of crater basin conservation[7].

$$Re=2\int (A/\pi)/Lb$$

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Re=0.75(less elongated index)

Where, A= Area of the crater π= 3.14, Lb= length of the basin

(Miller, 1953)

5.1.10. Circularity Ratio (Rc)

It is measured by the length and number of frequency of streams, geological structure of the crater, land use and land cover, climate, slope of the crater. The high value of circularity ratio indicates the late maturity stage of the topography of the crater. The lower the rate of circulatory ratio, the higher the rate of soil erosion at a particular crater

$$Rc = 4 \times \pi \times A / P^2$$

RC=1.62

$\pi = \pi$ value i.e.22/7 or 3.14

A= Area of the crater in m^2

P^2= Square of the perimeter

5.1.11. Compactness Constant (Cc)

Compactness coefficient of crater is the ratio of perimeter of crater to circumference of circular area of the crater, which equals the area of the crater. The Cc is independent of size of crater and dependant only on the slope. The compactness constant of Rajatkrishna crater is 0.75 more the compact crater, more the crater basin prioritization requires. (Gravelius 1914),

$$Cc = 0.2821 \, P/A^{0.5}$$

Cc=0.7

Where, A= Area of the crater basin, Km^2,

P= crater Basin perimeter, Km

(Hortan, 1945**)**

5.1.12. Lemniscate's (k)

lemniscates index states to determine the slope of the crater. High lemniscates (k) value for a crater shows that the crater occupies the maximum area in its regions of inception with number of streams the higher the Lemniscates value, the higher the soil erosion, requires high priority for priorization. (Chorley ,1957),

Lemniscate's (k) $K = Lb^2/4 \times A$

K=0.66

Where, Lb= length of the crater,

A= Area of the crater

(Chorley, 1957)

5.1.13. Crater Morphology

The Rajatkrishna crater has attracted the attention of the geologists and geomorphologists for investigation of its origin and the location on lateritic upland; it may be a geological wonder. crater is characterised by five morphological segments. The submittal convexity, the crater rim, the rectilinear slopes of the crater, crater basin or floor of the crater .Antriksha crater, Neel crater and Shindhu etc smaller craters are totally associated with Rajatkrishna crater. This region is characterized by lateritic soil and rocks and Table land. Maximum area is free of human interference, region is characterised by heavy rainfall. This seems one of the major causes of siltation inside the lake. The crater being a depression.[8]

5.1.13.1. Pediplain

Rajatkrishna craters' basin floor is characterised by Pediplain region due to intensive geomorphic process i.e. high rate of weathering and surface runoff under very high rainfall climatic conditions, representing final stage of the cyclic erosion. These are identified in the field work during pre monsoon season May 2023 and imageries due to grey tone

5.1.13.2. Composite Alluvial and colluvial fan

An alluvial plain or fan is a relatively flat landform which is created by the deposition of highlands eroded due to weathering and water flow in crater region. Whatever the weathered sediment presents at the rim that transports towards lower plain. Eroded material deposits at the floor region which consist of gravel, sand, silt or clay etc. The Rajatkriashna Crater interior records degradation processes leading to the formation of features such as rills gullies and debris flows, stream incising in the rim leading to form a fan delta. The rills and gully is a sediment transport system that transported the eroded materials from the surrounding region of the ejected blanket as well as from the crater rim to the crater

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basin floor to form the alluvial fan delta. Southwest part of the Rajatkrishna crater basin floor, with more concentrated with continuous water flow and sediment transport through the gully fan delta system, should have experienced the highest surface runoff, soil loss and siltation rate with respect to other sections.[9]

5.1.13.3 Pediment

Rajatkrishna crater and its smaller companion crater i.e Antariksha crater, neel crater and Shindhu crater, pediments are gently sloping areas or erosional surface of bed rock. Pediments may or may not be covered by a thin layer of alluvium and are mostly developed at the foot of the rim occurring along the crater basin. These landforms are showing light yellowish color and fine texture.[10]

5.1.14. Depth and diameter ratio of the crater

According to geologists, geomorphologists and hydrologists, depth and diameter of the crater usually remains their proportional relationship. Hence, because of the presence of the ultra structure of the crater, with very dynamic fluvial-hydrological components, it becomes very difficult to decipher the relationship between the diameter and depth of the carter. Diameter–depth relationship or the ratio of the crater is almost maintained in homogeneous lithology with structures. it is 0.8 that means almost near to the circular.[11] $\boldsymbol{D = Nh + M}$ Where, N is the ratio of diameter, h is the depth and D means the diameter of the crater, *M* is the critical size of the initial concavities.

5.1.15. Crater cavity volume

Cross profiles of the crater determines the volume of the crater cavity. It is calculated by at the lowest elevation at the basin floor and at the approximate elevation of the surrounding topography i.e at the ejecta blanket of the crater. The volume of the crater cavity is calculated which shows the result of bowl shape of the crater.[12]

5.1.16. Size and shape of the rock samples

The size, shape, color of the rocks observed in Rajatkrishna impact crater are varying in their nature. Most of the rocks are angular in shape and vary in its colour. Hence it is very important element as well as parameter which give result about the meteoritic crater mineral composition.

Fig.No.5. Rock samples observed in Rajatkrishna crater

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Sr.No	Crater name	Lat Ext	Long Ext	Height	Ac	Description
1.	RajatKrishna Crater	15.8775	74.0317	630	5.5	10 cm from top
2.	RajatKrishna Crater	15.8775	74.0317	628	5.5	20 cm from top
3.	RajatKrishna Crater	15.8775	74.0317	626	5.5	30 cm from top
4.	RajatKrishna Crater	15.8775	74.0317	624	5.5	40 cm from top
5.	RajatKrishna Crater	15.8775	74.0317	622	5.5	50 cm from top
6.	RajatKrishna Crater	15.8775	74.0317	620	5.5	60 cm from top

Table No.1 GPS location of the Rajatkrishna crater Soil Samples

6. CONCLUSION

Thus the Rajatkriashna Crater is a small impact crater. The potential of morphometric analysis in detecting and quantifying the geomorphology of impact crater. Morphometric analysis to derive and measure the morphological expression of the different sectors. As far as the stratigraphic application is concerned, morphometric analysis can be applied to retrieve stratigraphic sections within different simple craters, allowing a stratigraphic correlation among different craters. The relationships between d/D and a number of different variables, including crater size and shape. The Rajatkriashna Crater interior records degradational processes leading to the formation of features such as gullies and debris flows, and the gully incising in the rim leading to form a fan delta. The lake level within Rajatkriashna Crater appears is influenced by surface runoff that is active during the rainy season and Groundwater input effective during both the rainy and the dry seasons. The blanket ejecta extending outward from the crater rim has progressively been destroyed due to high surface runoff, therefore blanket ejecta is decreasing, unfortunately many scientific evidences which are important for understanding the crater formation. Thus Geometry of the crater, circularity index ,size, Associated smaller companion craters, the blanket ejecta, slope of the crater rim, mobility of the crater rim, sharpness of the crater rim, crater cavity index, crater morphology, depth and diameter index, size and shape of the rock samples etc these all morphometric parameters and elements are important to conformation and characterization for impact origin of the Rajatkrishna crater, Antriksha crater, Neel crater and Shindhu crater of Chaukul village of Sindhudurg district of Maharashtra, India.

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Refrences:

1. P.A. Bland and N.A. Artemieva, The impact rate of small asteroids at the Earth's surface. Large Meteorite Impacts, 2003, 4047.
2. Ahrens, T. J., and A. M. Rubin (1993), Impact-induced tensional failure in rock, J. Geophys. Res., 98, 1185 – 1203, doi:10.1029/92JE02679
3. Gareth S Collins et.al.(2022) The Impact catering process ELEMENTS, VOL. 8, PP. 25–30
4. Fudali, R. F., Milton. D. J., Fredriksson. K. and Dube., A. (1980), Morphology of Lonar Crater, India: Comparisons and implications, Moon Planets.
5. Kale V. S. Gupta Avijit (2002): "Introduction Geomorphology", Orient Longman Limited India.
6. Luo W. and Howard A. (2005) "Morphometric analysis of martian valley network basin using circularity functions' Journal of Geographical Research 110 (2005)
7. Strahler A.N. (1964) "Quantitive geomorphology of drainage basins and channel networks" 41 in handbook of applied Hydrology, edited by V.T. Chaw Mc Graw- Hill PP439.
8. Savindra Singh (2003): Principles of Geomorphology, Prayag Publication, Allahabad 'Morphometry of Drainage basin'.

9.Pike, R. J. (1980a), Control of crater morphology by gravity and target type - Mars, Earth, Moon, in Lunar and Planetary Science Conference Proceedings, vol. 11, edited by S. A. Bedini, pp. 2159–2189.
10. Pike, R. J. (1980b), Terrain Dependence of Crater Morphology on Mars: both yes and no, in Lunar and Planetary Institute Science Conference Abstracts, vol. 11, pp. 885–887.
11. Pike, R. J. (1988), Geomorphology of impact craters on Mercury, pp. 165–273, University of Arizona Press.
12.Pike, R. J., and P. A. Davis (1984), Toward a Topographic Model of Martian Craters from Photoclinometry, in Lunar and Planetary Institute Science Conference Abstracts, vol. 15, pp. 645– 646.
13.Goro Komatsu, P. Senthil Kumar, Kazuhisa Goto, Yasuhito Sekine, Chaitanya Giri, Takafumi Matsui.(2014)"Drainage systems of Lonar Crater, India: Contributions to Lonar Lake hydrology and crater degradation" , Planetary and Space Science.
14. Egyptian Journal of Pure and Applied Science (2016)"Drainage patterns network and hydrogeological functions, Wadi El Atfehy hydrographic basin, Eastern Desert, Egypt"
15. R. Terik Daly, Olivier S. Barnouin, Edward B. Bierhaus, Michael G. Daly et al. (2022)"The morphometry of small impact craters on Bennu: Relationships to geologic units, boulders, and impact armoring", Icarus,
16. Javed Mallick, Vikash Shivhare, Chander Singh, Majed Al Subih (2022). "Prioritizing Watershed Restoration, Management, and Development Based on Geo-Morphometric Analysis in Asir Region of Saudi Arabia Using Geospatial Technology" , Polish Journal of Environmental Studies,
17. I. Seyfipour, R. Mirghaderi, M. R. Bahaari(2022). "Buckling and stability of subsea HP/HT pipelines on laterally sloping seabeds" , Journal of Ocean Engineering and Marine Energy.
18. Ramesh L. Dikpal, T. J. Renuka Prasad, K. Satish. (2017) "Evaluation of morphometric parameters derived from Cartosat-1 DEM using remote sensing and GIS techniques for Budigere Amanikere watershed, Dakshina Pinakini Basin, Karnataka, India" , Applied Water Science.
19. Shanti Shwarup Mahto. (2018)"An Assessment of Inter-Seasonal Surface Water Level Fluctuation of Lonar Crater Lake, Maharashtra, India Using Multi-Temporal Satellite Dataset" , American Journal of Remote Sensing,
20. Gareth S. COLLINS. (2005) "Earth Impact Effects Program: A Web-based computer program for calculating the regional environmental consequences of a meteoroid impact on Earth" , Meteorites and Planetary Science,
21.Ajay Pratap Singh, Ajay Kumar Arya, Dhruv Sen Singh (2020) "Morphometric Analysis of Ghaghara River Basin, India, Using SRTM Data and GIS" , Journal of the Geological Society of India,
22. Praveen Kumar Rai, Pawan Kumar Chaubey, Kshitij Mohan, Praful Singh. (2017)"Geoinformatics for assessing the inferences of quantitative drainage Morphometry of the Narmada Basin in India", Applied Geomatics.